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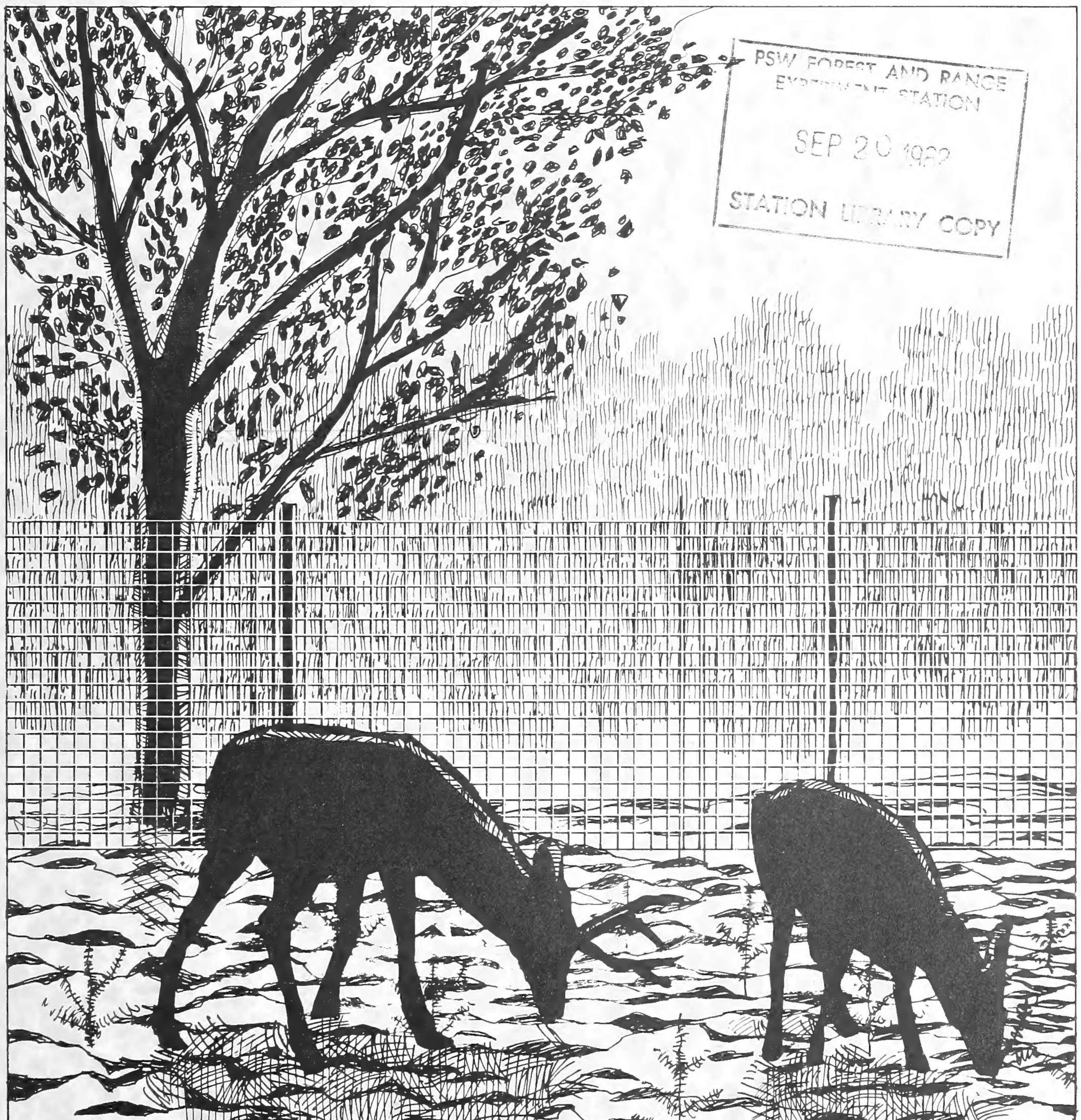
Acceptance by Black-Tailed Deer of Foliage Treated With Herbicides

Dan L. Campbell, James Evans, Gerald D. Lindsey
and William E. Dusenberry



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CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

Authors

DAN L. CAMPBELL and GERALD D. LINDSEY are research biologists and JAMES EVANS is project leader, Olympia, Washington, and WILLIAM E. DUSENBERRY is statistician, Denver, Colorado, all with the U.S. Department of the Interior, Fish and Wildlife Service.

Abstract

Campbell, Dan L.; Evans, James; Lindsey, Gerald D.; Dusenberry, William E. Acceptance by black-tailed deer of foliage treated with herbicides. Res. Pap. PNW-290. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; Olympia, WA: U.S. Department of the Interior, Fish and Wildlife Service, Forest-Animal Damage Control Research Project; 1981. 31 p.

To test their acceptance of foliage treated with herbicides, captive black-tailed deer were exposed to Douglas-fir seedlings and salal treated with standard formulations of 2,4,5-T, 2,4-D, atrazine, dalapon, fosamine, and glyphosate herbicides. Carriers were diesel oil and water. Tests were made from November 1977 through February 1978. Deer readily browsed 2,4,5-T treatments and most formulations of 2,4-D in oil compared with oil alone, but showed rejection of some phytotoxic glyphosate treatments. Consumption of herbicide-treated foliage did not cause noticeable health problems in test animals.

Keywords: Herbicides, browse preference, deer (black-tailed), Odocoileus hemionus columbianus, Douglas-fir, Pseudotsuga menziesii, salal, Gaultheria shallon, atrazine, 2,4,5-T, 2,4-D.

Summary

Herbicides are an integral part of forest management in the Pacific Northwest. Effects of herbicides on forest vegetation are fairly well known, but their effects on wildlife are relatively unknown.

To test acceptance by black-tailed deer of foliage treated with herbicides, we treated dormant Douglas-fir seedlings and salal with standard herbicide formulations and exposed them to two groups of captive deer in large enclosures. The deer readily browsed most standard formulations regardless of herbicide, carrier, or plant material tested without obvious effects on their behavior or health. Formulations of 2,4,5-T from 1.12 to 5.60 kilograms active ingredient per hectare in 93.45 liters per hectare of water or diesel oil carrier had no significant effect on deer browsing. Significant interaction of 2,4-D and carriers occurred with 2,4-D in 100-percent diesel oil, resulting in increased acceptance of plant material compared with 100-percent diesel oil alone. Reduced acceptance of seedlings treated with glyphosate, which later proved phytotoxic, indicated possible deer sensitivity to either the herbicide or physiological change of Douglas-fir; we suspect the latter. Deer accepted Douglas-fir treated with atrazine, fosamine, and dalapon. Douglas-fir treated with atrazine formulations showed significantly better growth than controls.

Results suggest that further field study should be conducted on deer feeding preferences under operational spraying programs. Modification of formulations might reduce acceptance of treated browse plants by deer in the field.

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Contents

Introduction

Herbicides are commonly used to manage vegetation on National Forests and other lands to promote reforestation and wildlife. In the Western United States, foliage sprays are used to control unwanted vegetation for conifer release and site preparation or conversion of brush fields to productive forests (Dimock et al. 1976; Gratkowski 1971, 1977, 1978; Newton 1975; Stewart 1974). The sprays have also been used to improve forage for wildlife (Krefting and Hansen 1969; Kufeld 1977; Mueggler 1966). Some have even promoted dominance of certain forbs (Newton and Overton 1973) that have been useful in reducing damage to Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) by black-tailed deer (Odocoileus hemionus columbianus Richardson) (Campbell and Evans 1975, 1978).

Major reforestation goals call for rehabilitation of several million acres of brush fields in the Pacific Northwest (Gratkowski et al. 1973). Intensive forest management also frequently requires regular treatment of young plantations with herbicides to reduce brush competition (Newton 1970). These brushy areas are prime habitat for wildlife. Added to the general concern about safe use of herbicides in forests (Evans 1974; Norris 1971; Plumb et al. 1977)is considerable concern about effects of herbicides on wildlife (Juntenen and Norris 1972; Leng 1977; Meehan et al. 1974; Mullison 1970; Thilenius and Brown 1976). Effects on deer consuming treated foliage and the possible conveyance of herbicide residues to human beings are of particular concern (Dost 1978; Newton and Snyder 1978).

Despite numerous evaluations of positive and negative effects of herbicides, limited study has been done on direct consumption of herbicide-treated plants by animals (Scifres 1977). Although numerous chemicals have been tested on black-tailed deer (Campbell and Bullard 1972; Campbell and Evans 1977; Gauditz 1977), only one recently registered forest herbicide--Roundup® (glyphosate)--has been evaluated on black-tailed deer (Sullivan and Sullivan 1979). We conducted tests to determine if black-tailed deer selectively browsed vegetation treated with glyphosate and five other registered herbicides. Label information on herbicides is given in Appendix A.

Methods

Tests were conducted from November 1977 through February 1978 at the Forestry Sciences Laboratory at Olympia, Washington. Two groups of captive black-tailed deer served as test animals. Douglas-fir and salal (Gaultheria shallon Pursh)--both typical deer browse plants--were sprayed with selected herbicide formulations, and the amount of browsing by deer was measured. The effects of the herbicides on Douglas-fir seedling growth and survival were also measured.

Test Animals

In Douglas-fir tests, we used a group of four bucks (1 subadult and 3 adults) and four does (2 subadults and 2 adults). In salal tests, three adult deer (1 buck and 2 does) were used. The groups were tested in large, partially wooded enclosures (fig. 1). Each deer had free access to treated materials, natural forage, pelleted food, and water.

Figure 1.--Black-tailed deer acceptance of Douglas-fir seedlings treated with herbicides being tested in a U.S. Fish and Wildlife Service enclosure at Olympia, Washington.

Plant Materials

The Douglas-fir seedlings tested, averaging 20-cm tall, were grown in containers by the Weyerhaeuser Company. The seedlings were washed five times with cold water by pressure spray and air dried overnight under an outdoor shelter. The seedlings were spaced in racks for uniform spray treatment(fig. 2).

Figure 2.--Placement of container-grown Douglas-fir seedlings in racks to allow uniform coverage of herbicide spray.

Salal branches of uniform size with 10 leaves per branch were freshly cut from a nearby stand before each test. The salal branches were also washed and placed in racks for treating.

Herbicides and Carriers

Six registered herbicides were formulated in tap water, 10-percent diesel oil in water, or 100-percent diesel oil. Chevron Diesel Fuel No. 2 was used in all oil formulations. Herbicides tested were:

Trade name	Common name	Chemical name
Esteron 245®	2,4,5-T	propylene glycol butyl ether ester of 2,4,5-trichlorophenoxyacetic acid.
Esteron 99 Concentrate®	2,4-D	propylene glycol butyl ether ester of 2,4-dichlorophenoxyacetic acid.
AAtrex 50W®	atrazine	2-chloro-4-ethylamino-6-isopropylamino-1,3,5-triazine.
Dowpon M®	dalapon	sodium salt of 2,2-dichloropropionic acid.
Krenite®	fosamine	ammonium ethyl carbamoylphosphonate
Roundup®	glyphosate	isopropylamine salt of N-(phosphonomethyl) glycine.

Formulation and Application

Herbicides were mixed in the laboratory according to label instructions and applied at a uniform rate of 93.45 liters per hectare. The amount of active ingredient applied was based on recommended rates for each herbicide, from 1.12 to 8.96 kilograms per hectare. Application to foliage was standardized by spraying droplets about 200 microns in diameter at a pressure of 0.91 kilograms per square centimeter from about 1 meter above the plants (fig. 3). Spray equipment was described by Duffy and Schneider (1974).

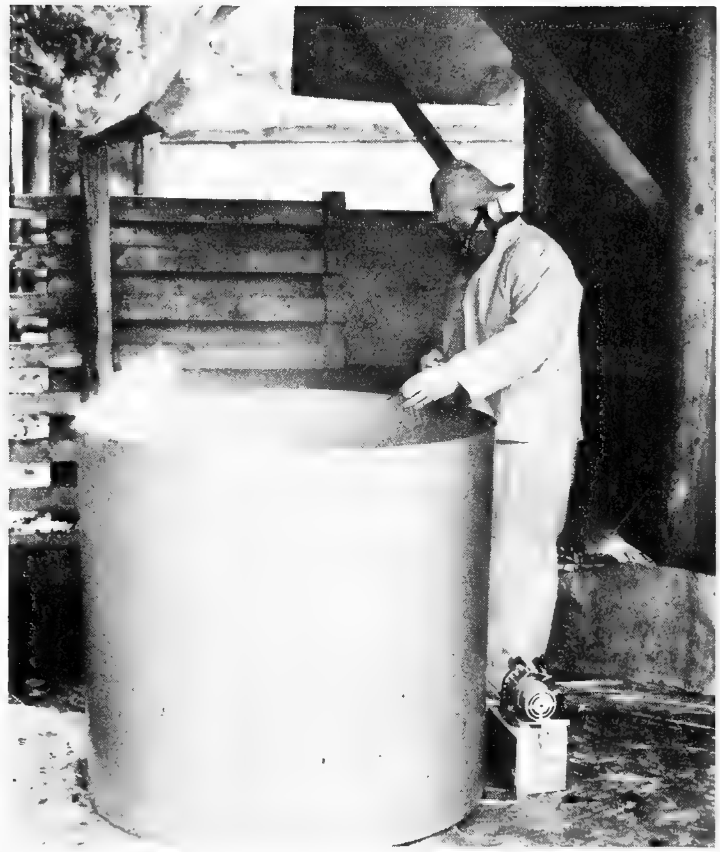

Figure 3.--Herbicide formulations being sprayed on vegetation for exposure in black-tailed deer acceptance tests.

Treatments

Six tests were conducted, four with Douglas-fir seedlings and two with salal branches. Herbicide treatment combinations with carriers are listed in table 1. All plant materials that served as controls were sprayed with water.

Table 1--Levels of herbicides and carriers used in the treatment combinations for Douglas-fir and salal tests

Plant	Test	Carrier (diesel oil in water)	Herbicide	Rate of application
		Percent		Kilograms per hectare
Douglas-fir	1A	0 (water), 10, 100	2,4,5-T	0, 1.12, 2.24, 3.36, 4.48, 5.60
	2A	0, 10, 100	2,4-D	0, 1.12, 2.24, 3.36, 4.48, 5.60
	3A	0, 10, 100	50% 2,4,5-T + 50% 2,4-D	0, 1.12, 2.24, 3.36, 4.48, 5.60
	4A	0 (water only)	control	0
			2,4-D	1.12
			fosamine	2.24, 3.36, 4.48, 5.60
			glyphosate	1.12, 2.24, 3.36, 4.48
			dalapon	2.24, 4.48, 6.72, 8.96
			atrazine	2.24, 3.36, 4.48, 5.60
Salal	1B	0, 10, 100	2,4,5-T	1.12, 5.60
			2,4-D	1.12, 5.60
	2B	0, 10, 100	50% 2,4,5-T + 50% 2,4-D	1.12, 2.24, 4.48, 5.60

Test Design and Analysis

Douglas-fir tests.--Treated seedlings were planted 1 meter apart in five blocks in a cultivated area inside a 1-hectare deer enclosure (fig. 4). In each block were 36 rows of 10 trees. Each row of 10 trees was an experimental unit to avoid the problems of dichotomous data that would result if individual trees were the experimental unit. Two rows of each treatment combination were in each block, and rows were randomly selected for application of treatment within each block. Each test compared 18 different treatments of 100 seedlings per treatment for a total of 180 rows. The actual measurement was the proportion of seedlings browsed in each row of 10 at a given time.

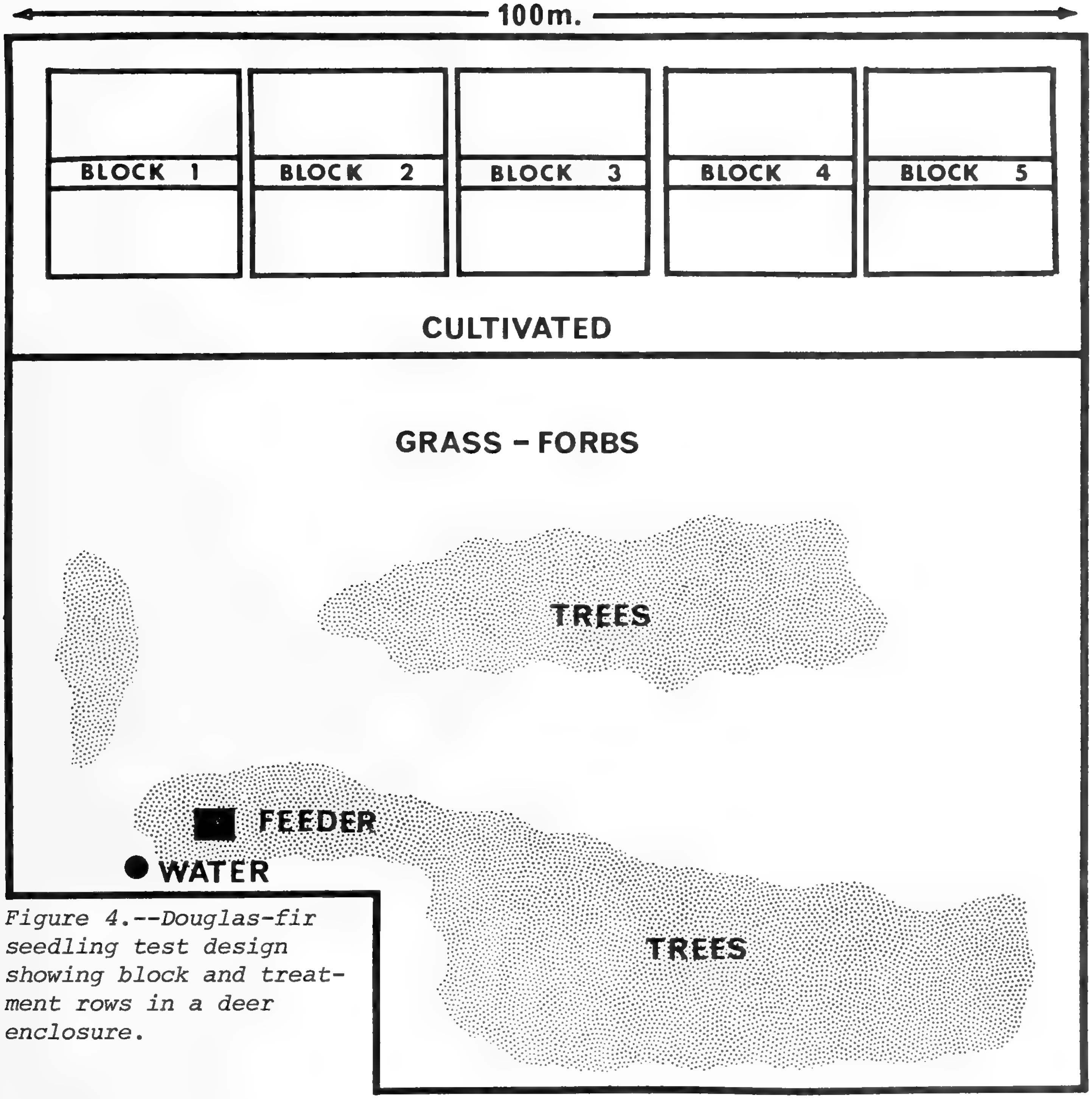

Figure 4.--Douglas-fir seedling test design showing block and treatment rows in a deer enclosure.

Measurements of browsing were started a few hours after planting and subsequent observations made several times each day. To complete a test, deer were required to browse the terminal of 60 percent of the water-sprayed control seedlings within 21 days. Measurements at observation times nearest the 60-percent requirement were selected for analysis of deer preference. Additional measurements were taken for several days for further analysis of preference. The proportion of seedlings browsed (p) was analyzed by the arc sin $\sqrt{p}$ transformation to normalize the proportion data before analysis of variance. Statistically significant main effects or interactions in the analysis of variance were further analyzed by Duncan's multiple-range test applied to the appropriate arc sin $\sqrt{p}$ transformed means.

Salal tests.--Untreated and treated salal branches were stapled to paired stakes (A and B in fig. 5) in each of five blocks spaced throughout a 0.15-hectare enclosure. Either an untreated or treated branch was assigned to stakes A and B at random. Twelve treatments were randomly located within each block. For each test, 120 pairs of treated and untreated salal branches were used.

Browsing was initially measured hourly for the first 6 hours until darkness and then periodically thereafter. A branch was considered browsed if one or more leaves were missing. The observation at the time nearest to when 60 percent of the control branches had been browsed was selected for the primary analysis for deer preference. The differences in numbers of leaves eaten between paired control and treated branches (control minus treated) were tested by analysis of variance to detect treatment effects, and Duncan's multiple-range test was used to separate the means in significant treatment effects.

Douglas-Fir Phytotoxicity

Immediately after Douglas-fir tests were installed, a group of 25 seedlings of each treatment was planted in a separate nursery. These seedlings were checked during the deer tests for any obvious phytotoxicity that might affect deer acceptance and checked again at budburst to determine if trees were alive. Seedlings were also measured 1.5 months after budburst to determine length of new growth in centimeters. The measurements of new growth were analyzed using analysis of variance. Statistically significant main effects of interactions in the analysis of variance were further analyzed using Duncan's multiple-range test applied to appropriate means. Seedling mortality rates were compared among various treatments using Chi-square tests for homogeneity.

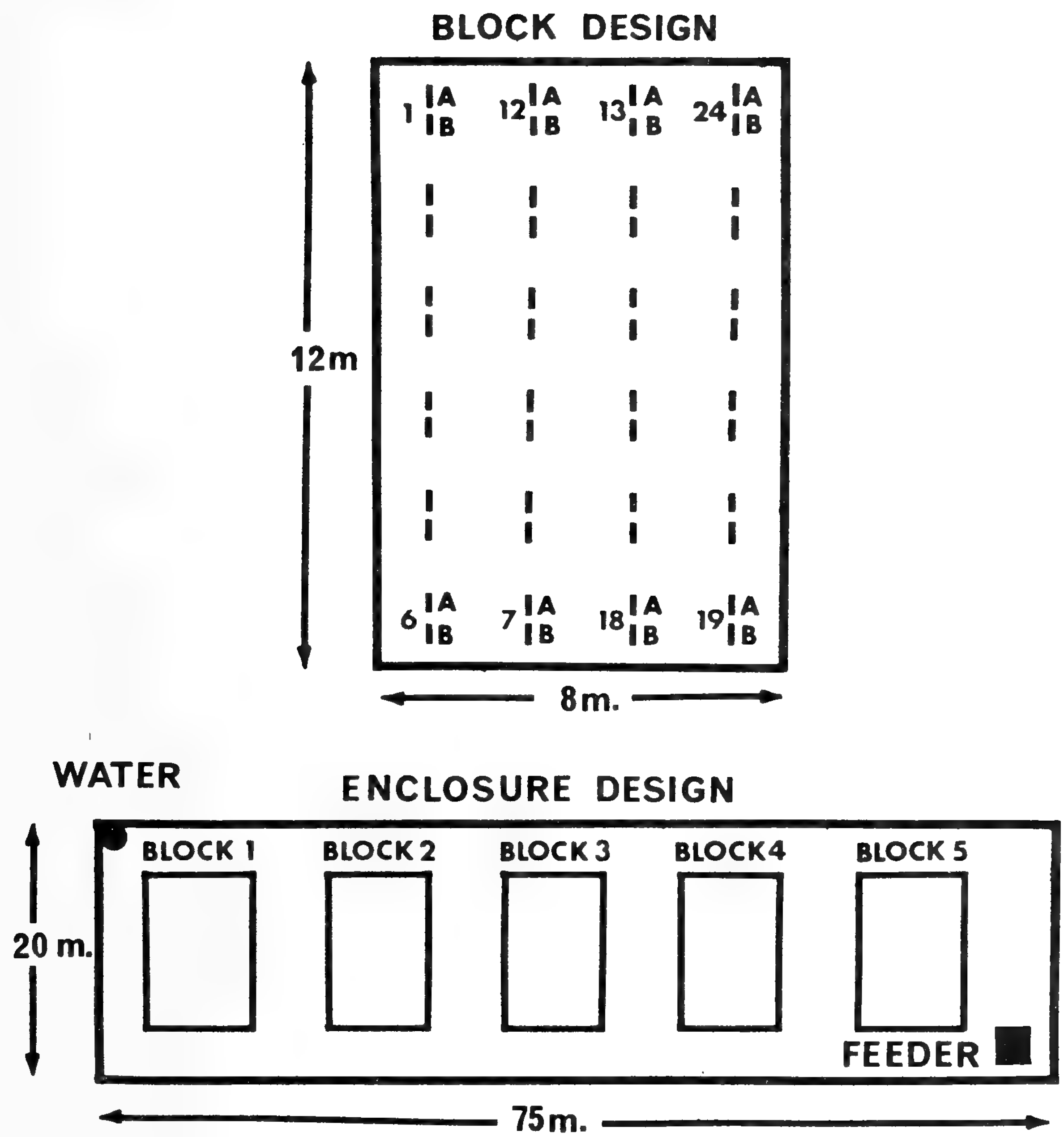

Figure 5.--Salal-test design showing treatment and block location in a deer enclosure.

Deer readily browsed Douglas-fir seedlings and salal cuttings during all tests. (See appendix B - tables 2 through 18 for specific test data.) Temperatures averaged 5°C and relative humidity about 100 percent during each test. Rainfall occurred only during the last Douglas-fir test. Deer behavior and health were not obviously affected by feeding on foliage treated with herbicides or diesel oil during the observation period.

Douglas-Fir Tests

The first Douglas-fir test required 3 days of exposure for the eight deer to browse 60 percent of the untreated control seedlings. The next three tests required an average of only 0.9-day exposure to obtain 60-percent acceptance. Each test was concluded in 4 to 10 days--nearly all seedlings in each test were browsed in this time.

2,4,5-T formulations (TEST 1A).--No significant difference in acceptance was found between controls and 2,4,5-T treatments of 1.12, 2.24, 3.36, 4.48, and 5.60 kilograms per hectare at either 3 days (table 2) or 5 days (table 3). After 5 days of exposure, over 90 percent of most seedling treatments were browsed. Initially, deer showed no significant preference for Douglas-fir treated with water or 10-percent oil (table 4), but they significantly preferred those treated with water or 10-percent diesel oil over 100-percent diesel oil after 5 days.

2,4-D formulations (TEST 2A).--After 0.8-day exposure, seedlings treated with 2,4-D at 1.12, 2.24, 3.36, 4.48, and 5.60 kilograms per hectare in water or in 10-percent diesel oil showed few significant differences in acceptance (table 5). Formulations containing 2.24 and 5.60 kilograms per hectare of 2,4-D in 100-percent diesel oil had significantly higher acceptance than 100-percent diesel oil alone. This significant difference was lost after 1.8 days' exposure (table 6). Deer generally preferred water and 10-percent diesel oil carriers over 100-percent diesel oil (table 7) during these exposure periods.

Mixed formulations of 2,4,5-T and 2,4-D (TEST 3A).--Few significant differences occurred in browsing among control and half-and-half mixtures of 2,4,5-T and 2,4-D. The formulations containing 5.60 kilograms per hectare of 2,4,5-T and 2,4-D were browsed less (but not significantly less) than the controls for the first day only (table 8). After 1.9 days, the 100-percent diesel oil-herbicide formulations at 0, 1.12, 3.36, and 5.60 kilograms active herbicide per hectare were browsed significantly less than the controls (water only, see table 9). Browsing was significantly lower for treatments of 100-percent diesel oil than for 10-percent oil or water treatments at 1.0 and 1.9 days of exposure (table 10).

Other herbicide formulations (TEST 4A).--Only a few of these herbicides, formulated only in water, were browsed significantly less than controls after 0.9-day exposure (table 11). We do not know the effect of light rainfall (0.51 centimeter) during this period. No significant difference was found between 1.12 kilograms per hectare of 2,4-D (standard) and water-treated controls. Most formulations of fosamine, dalapon, and atrazine were readily browsed by deer. Atrazine at 2.24 kilograms per hectare was browsed significantly less than controls and significantly less than atrazine at 3.36, 4.48, and 5.60 kilograms per hectare. Browsing was also significantly lower for formulations of glyphosate at 2.24, 3.36, and 4.48 kilograms per hectare than for controls, and it was significantly higher for 1.12 kilograms per hectare glyphosate than for 3.36 and 4.48 kilograms per hectare. After exposure for 1.9 days, nearly all seedlings of all formulations were browsed, although glyphosate treatments at 3.36 and 4.48 kilograms per hectare were still browsed least (at 88 percent and 89 percent, respectively).

Salal Tests

Formulations of 2,4,5-T and 2,4-D had little effect on consumption of salal. In each test, the three deer browsed 60 percent of the 120 untreated (control) salal branches in less than 0.4 day. Almost all of the 240 branches and 2,400 leaves in each test were completely browsed by the 2d day.

2,4,5-T and 2,4-D formulations (TEST 1B).--Results of testing 2,4,5-T and 2,4-D separately on salal are summarized in table 12. After 0.4-day exposure, deer showed a significant preference for 2,4,5-T at 1.12 kilograms per hectare over 5.60 kilograms per hectare of 2,4,5-T and 1.12 kilograms per hectare of 2,4-D. Deer preferences among herbicide treatments disappeared after 1 day when nearly everything was uniformly browsed. Water(only)-treated salal was significantly preferred over all herbicide treatments except for 2,4,5-T at 1.12 kilograms per hectare after 0.4-day exposure. The herbicide carriers, including 100-percent diesel oil, had no significant effect on deer acceptance of salal.

Formulations with half-and-half mixtures of 2,4,5-T and 2,4-D (TEST 2B).--After 0.4-day exposure, deer browsing showed no significant difference for salal treated with any of the formulations with half-and-half mixtures of 2,4,5-T and 2,4-D applied at 1.12, 2.24, 4.48, and 5.60 kilograms active herbicide per hectare (table 13). After exposure for 1 day, however, deer showed significant preference for treatments of 4.48 and 5.60 kilograms per hectare over treatments of 2.24 kilograms per hectare. Diesel oil had no obvious effect on preferences in this test. Water(only)-treated salal was significantly preferred over all herbicide treatments after 0.4-day exposure, but this significant preference was only apparent at 1.12 and 2.24 kilograms active herbicide per hectare after exposure for 1 day.

Phytotoxicity and Seedling Growth

The early December applications of 5.60 kilograms per hectare of 2,4,5-T in water or 10-percent diesel oil exhibited no reduction in seedling growth (table 14). Most 100-percent diesel oil formulations were associated with reduced seedling growth and may have contributed to increased mortality of Douglas-fir seedlings.

Some formulations of 2,4-D in water or in 10-percent diesel oil applied in mid-December had a significant effect on Douglas-fir seedling growth (table 15). Formulations that resulted in significantly reduced growth were 3.36 kilograms per hectare in water and 5.60 kilograms per hectare in 10-percent diesel oil. Seedlings treated with 2.24, 3.36, 4.48, and 5.60 kilograms per hectare in 100-percent diesel oil exhibited significantly reduced growth in comparison to controls. Also, seedlings treated with 1.12 kilograms per hectare of 2,4-D in water in December grew significantly more than seedlings treated with the same formulation in February (table 16).

Eight of the nine formulations with half-and-half mixtures of 2,4,5-T and 2,4-D containing 3.36 or more kilograms per hectare active herbicide applied in mid-January, as well as 2.24 kilograms per hectare in 100-percent diesel oil, significantly reduced height growth of Douglas-fir seedlings (table 17). Again, lower rates of the mixed herbicides and oil-carrier treatments did not significantly affect growth.

Douglas-fir seedlings treated with 3.36 and 5.60 kilograms per hectare of atrazine showed a significant height increase over control seedlings (table 18). The mid-February applications of glyphosate, on the other hand, resulted in reduced growth, 28-percent mortality at 1.12 kilograms per hectare, and 88-percent total mortality for treatments at 2.24, 3.36, and 4.48 kilograms per hectare. Fosamine formulations did not affect growth at 2.24 and 5.60 kilograms per hectare, but seedlings treated at 3.36 and 4.48 kilograms per hectare showed significantly less growth than controls. Dalapon formulations at 4.48, 6.72, and 8.96 kilograms per hectare resulted in reduced seedling growth; 2.24 kilograms per hectare did not.

Discussion and Conclusions

None of the 61 forest herbicide treatments tested prevented browsing by these deer. Although plants treated with water or 10-percent diesel oil were initially preferred over those treated with 100-percent diesel oil, these differences became insignificant as browsing progressed and deer had fewer choices. The overall high acceptance of herbicide formulations and carriers is not surprising in view of the known acceptance of other chemicals that have shown high candidacy as deer repellents (Campbell and Bullard 1972).

Formulations of 2,4,5-T from 1.12 to 5.60 kilograms per hectare apparently had little or no effect on deer feeding preferences, 2,4-D in 100-percent diesel oil produced higher deer acceptance than pure diesel oil alone, and all formulations of fosamine and dalapon, and all formulations of atrazine except a 2.24 kilograms-per-hectare treatment, were readily browsed. The phytotoxic effects of glyphosate should be investigated further before field application to dormant Douglas-fir seedlings. The reduced acceptance of glyphosate-affected Douglas-fir seedlings should also be investigated.

Deer showed no obvious adverse effects from herbicides or herbicide formulations; however, only general observations were made on the health of the deer. Long-term effects of these herbicide formulations on deer are not known. If 2,4-D and 2,4,5-T herbicide formulations have no adverse effects on deer as reported by Norris (1971), their ingestion of treated foliage would cause no concern. If food preferences by ruminants are severely altered by herbicide ingestion (Sjöden and Söderberg 1978), the degree of acceptance of treated foliage could be important. More studies are warranted on seasonal variation in deer browsing related to herbicide use and on physiological and ecological effects of herbicides.

Apparent interactions of carriers and herbicides, timing of spray application on dormant Douglas-fir, and effects of some herbicides alone on growth of seedlings produced some noteworthy results. For example, diesel oil alone or at 10-percent in water had no significant effect on spring growth of treated seedlings; however, seedlings treated with several formulations of 2,4,5-T and 2,4-D alone or mixed together in 100-percent diesel oil showed less growth than controls. Using water instead of oil would not necessarily offset this problem. Some treatments of 2,4-D at 1.12 kilograms per hectare in water in December grew as well as control seedlings, but the same treatment applied in February produced a significant reduction in seedling growth. Proper timing could apparently reduce adverse effects of these herbicide formulations on Douglas-fir. Based on our tests and other results, proper timing and application of glyphosate seems to be a critical factor in minimizing its phytotoxic effects on Douglas-fir seedlings.

Our tests and others (Newton and Overton 1973) indicate a direct positive effect of atrazine on growth of Douglas-fir. Deer damage to this increased growth should be determined, because a problem with deer browse was attributed to increased crude protein with simazine (2-chloro-4,6-bis(ethylamino)-s-triazine) in young balsam firs (Abies balsamea) by Morgan and McCormack (1973). Some combined properties of herbicides and repellents might be used in developing methods to reduce deer browsing on treated plants, including Douglas-fir, to prevent deer from consuming specific herbicides and damaging trees.

Lastly, to compensate for differences in response of individual deer, we suggest using this herd approach in acceptance tests to simulate the group feeding behavior that occurs under field conditions. Phytotoxicity should be a strongly considered factor in evaluating deer acceptance of herbicide-treated plants. The generally high acceptance of herbicide-treated foliage found in these tests suggests that field evaluations should be done to determine long-term benefits and adverse effects of operationally applied herbicides on deer and deer habitat in the Pacific Northwest.

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Metric Equivalents

1 centimeter = 0.394 inch
1 meter = 3.28 feet
1 hectare = 2.47 acres

1.12 kilograms/hectare = 1 pound/acre
2.24 kilograms/hectare = 2 pounds/acre
3.36 kilograms/hectare = 3 pounds/acre
4.48 kilograms/hectare = 4 pounds/acre
5.60 kilograms/hectare = 5 pounds/acre
6.72 kilograms/hectare = 6 pounds/acre
8.96 kilograms/hectare = 8 pounds/acre

93.45 liters/hectare = 10 gallons/acre

0 degrees Celsius
= 32 degrees Fahrenheit

5 degrees Celsius
= 41 degrees Fahrenheit

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Appendix A

Labels of the Six Herbicides Tested for Acceptance by Black-Tailed Deer

DOW ESTERON 245 LOW VOLATILE BRUSH AND WEED KILLER

Acid Equivalent: 4 pounds per gallon
Active Ingredient:
2,4,5-Trichlorophenoxyacetic Acid Propylene Glycol Butyl Ether Esters 67.7 percent
2,4,5-Trichlorophenoxyacetic Acid Equivalent 44.1 percent
USDA Reg. No. 464-205

DOW ESTERON 99 CONCENTRATE LOW VOLATILE WEED KILLER

Acid Equivalent: 4 pounds per gallon
Active Ingredient:
2,4-Dichlorophenoxyacetic Acid Propylene Glycol Butyl Ether Esters 72.8 percent
2,4-Dichlorophenoxyacetic Acid
USDA Reg. No. 464-201

CIBA-GIEGY AATREX 80W HERBICIDE

Batch No. FL-751924
ARS No. 2351/75

DOW DOWPON M GRASS KILLER

Active Ingredients:
Sodium salt of dalapon 72.5 percent
Magnesium salt of dalapon 12.0 percent
Total active ingredients equivalent to 74 percent dalapon (2,2-dichloropropionic acid)
EPA Reg. No. 464-402-2A

MONTSANTO ROUNDUP HERBICIDE

4 pounds of isopropylamine salt of N-(phosphonomethyl) glycine per U.S. Gallon
3 pounds of equivalent acid glyphosate per U.S. Gallon
Active Ingredient:
Isopropylamine salt of Glyphosate 41.0 percent
EPA Reg. No. 524-308-AA

DUPONT KRENITE

4 pounds per gallon concentrate
Active Ingredient:
Ammonium ethyl carbamoylphosphonate
EPA Reg. No. 352-376

Appendix B

Table 2--Deer browsing on Douglas-fir seedlings treated with standard 2,4,5-T herbicide formulations after 3 days of exposure (Test 1A)

Rate of application	Diesel oil carrier[1]	Detransformed means[2]
Kilograms per hectare	Percent	Percent
2.24	100	74.1
0	10	71.7
1.12	0	68.8
2.24	0	68.4
1.12	10	67.7
0	0	66.3
5.60	10	65.1
4.48	10	63.6
5.60	0	63.2
0	100	62.0
3.36	10	61.2
5.60	100	60.7
3.36	0	58.3
4.48	100	55.9
4.48	0	53.2
2.24	10	49.6
3.36	100	44.5
1.12	100	40.8

[1] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[2] No significant differences were found in the treatment levels.

Table 3--Deer browsing on Douglas-fir seedlings treated with standard 2,4,5-T herbicide formulations after 5 days of exposure (Test 1A)

Rate of application	Diesel oil carrier[1]	Detransformed means[2]
Kilograms per hectare	Percent	Percent
0	0	98.8
1.12	0	98.2
4.48	10	96.6
0	10	96.5
1.12	10	96.0
3.36	0	95.3
2.24	0	95.2
5.60	0	95.1
2.24	10	95.1
0	100	95.0
4.48	100	94.2
4.48	0	94.0
5.60	10	93.5
2.24	100	93.2
3.36	10	91.6
5.60	100	87.0
3.36	100	85.2
1.12	100	77.8

[1] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[2] No significant differences were found in the treatment levels.

Table 4--Deer browsing preferences for carriers used in formulations of 2,4,5-T herbicide on Douglas-fir seedlings after 3 days and 5 days of exposure (Test 1A)[1]

Diesel oil carrier[2]	Detransformed means[3]	
	3 days	5 days
	Percent	
0	63.1 a	96.3 a
10	63.3 a	94.9 a
100	56.5 a	89.4 b

[1] See tables 2 and 3 for specific herbicide/carrier interaction means.

[2] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[3] Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 5--Deer browsing preferences for standard formulations of 2,4-D herbicide on Douglas-fir seedlings after 0.8 day exposure (Test 2A)

Rate of application	Diesel oil carrier[1]	Detransformed means[2]
Kilograms per hectare	Percent	Percent
3.36	10	85.7 a
0	0	81.8 a b
1.12	0	81.7 a b
0	10	76.6 a b c
4.48	0	75.8 a b c
2.24	0	75.7 a b c
2.24	10	74.7 a b c
2.24	100	73.0 a b c
5.60	0	72.7 a b c
5.60	100	71.7 a b c
1.12	10	70.9 a b c
4.48	10	69.1 a b c d
4.48	100	62.0 a b c d
3.36	0	61.3 a b c d
1.12	100	58.8 b c d
5.60	10	56.7 b c d
3.36	100	53.2 c d
0	100	42.6 d

[1] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[2] Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 6--Deer browsing preferences for standard formulations of 2,4-D herbicide on Douglas-fir seedlings after 1.8 days of exposure (Test 2A)

Rate of application	Diesel oil carrier[1]	Detransformed means[2]
Kilograms per hectare	Percent	Percent
5.60	0	99.6 a
2.24	10	99.4 a b
3.36	10	99.4 a b c
2.24	0	99.1 a b c
0	0	98.4 a b c
4.48	0	98.0 a b c
0	10	97.0 a b c
1.12	0	97.0 a b c
5.60	10	97.0 a b c
2.24	100	95.9 a b c
1.12	100	95.3 a b c
5.60	100	95.2 a b c
1.12	10	95.0 b c
4.48	100	94.1 b c
3.36	100	94.0 c
4.48	10	93.8 c
3.36	0	91.8 c
0	100	88.4 c

[1] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[2] Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 7--Deer browsing preferences for carriers used in formulations of 2,4-D herbicide on Douglas-fir seedlings after 0.8 day and 1.8 days of exposure (Test 2A)[1]

Diesel oil carrier[2]	Detransformed means[3]	
	0.8 days	1.8 days
- - - - - - - - - - - - Percent	- - - - - - - - - - - -	
0	75.1 a	97.8 a
10	72.7 a	97.3 a
100	60.4 b	94.0 b

[1] See tables 5 and 6 for specific herbicide/carrier interaction means.

[2] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[3] Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 8--Deer browsing on Douglas-fir seedlings treated with formulations containing half-and-half mixtures of 2,4,5-T and 2,4-D herbicides after 1.0 day exposure (Test 3A)

Rate of application	Diesel oil carrier[1]	Detransformed means[2]
Kilograms per hectare	Percent	Percent
0	0	82.3
0	10	80.1
2.24	0	76.5
2.24	10	75.4
1.12	10	70.8
1.12	0	66.5
4.48	10	65.8
4.48	0	62.6
5.60	10	62.5
5.60	0	61.4
3.36	10	59.7
4.48	100	45.7
1.12	100	40.5
2.24	100	39.1
3.36	100	35.9
0	100	33.8
5.60	100	29.3

[1] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[2] No significant differences were found in the treatment levels.

Table 9--Deer browsing preferences for formulations containing half-and-half mixtures of 2,4,5-T and 2,4-D herbicides after 1.9 days of exposure (Test 3A)

Rate of application of combined herbicides	Diesel oil carrier[1]	Detransformed means[2]
Kilograms per hectare	Percent	Percent
1.12	10	99.1 a
0	10	99.1 a
2.24	0	98.2 a b
3.36	0	98.0 a b
5.60	10	98.0 a b
0	0	97.6 a b c
4.48	10	96.2 a b c d
5.60	0	95.6 a b c d
1.12	0	94.2 a b c d
2.24	10	93.0 a b c d
4.48	0	91.4 a b c d e
3.36	10	90.1 b c d e
4.48	100	87.9 c d e f
2.24	100	87.9 c d e f
0	100	85.4 d e f
1.12	100	78.3 e f
5.60	100	74.3 f
3.36	100	73.1 f

[1] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[2] Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 10--Deer browsing preferences for carriers used in formulations containing half-and-half mixtures of 2,4,5-T and 2,4-D on Douglas-fir seedlings after 1 day and 1.9 days of exposure (Test 3A)[1]

Diesel oil carrier[2]	Detransformed means[3] 1.0 day	Detransformed means[3] 1.9 days
	Percent	
0	70.4 a	96.1 a
10	69.3 a	96.5 a
100	37.3 b	81.5 b

[1] See tables 8 and 9 for specific herbicide/carrier interaction means.

[2] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[3] Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 11--Deer browsing preference after 0.9-day exposure for standard formulations of fosamine, dalapon, atrazine, glyphosate, and 2,4-D herbicides applied to Douglas-fir seedlings in water carrier (Test 4A)

Rate of application	Formulation	Detransformed means[1]
Kilograms per hectare		Percent
4.48	fosamine	89.6 a
0	water only	88.5 a b
8.96	dalapon	86.4 a b
4.48	atrazine	86.4 a b
5.60	atrazine	85.8 a b
3.36	atrazine	84.8 a b
2.24	dalapon	82.9 a b
2.24	fosamine	82.5 a b
3.36	fosamine	82.1 a b c
5.60	fosamine	80.2 a b c
4.48	dalapon	77.9 a b c
1.12	glyphosate	71.7 a b c d
1.12	2,4-D	70.6 a b c d
6.72	dalapon	68.3 b c d e
2.24	atrazine	59.6 c d e f
2.24	glyphosate	50.9 d e f
4.48	glyphosate	46.2 e f
3.36	glyphosate	39.6 f

[1] Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 12--Deer browsing preferences for water-treated salal and salal treated with 2,4,5-T and 2,4-D herbicide formulations after 0.4 day and 1.0 day of exposure (Test 1B)

Herbicide	Rate of application	Mean differences[1] 0.4 day	Mean differences[1] 1.0 day
	Kilograms per hectare	Percent	Percent
2,4,5-T	1.12	0.03 a	-0.17 a
2,4-D	5.60	1.33 a b	0.20 a
2,4,5-T	5.60	2.40 b	1.27 a
2,4-D	1.12	2.53 b	0.63 a

[1] A mean difference of 0.00 would show equal browsing of herbicide and water treatments. A negative number indicates preference for an herbicide treatment and a positive number indicates preference for a water treatment. Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 13--Deer browsing preferences for water-treated salal and salal treated with herbicide formulations containing a half-and-half mixture of 2,4,5-T and 2,4-D after 0.4 day and 1.0 day of exposure (Test 2B)

Rate of application	Mean differences[1] 0.4 day	Mean differences[1] 1.0 day
Kilograms per hectare	Percent	Percent
5.60	1.50 a	0.07 a
4.48	1.17 a	0.13 a
1.12	1.73 a	0.87 a b
2.24	1.43 a	1.50 b

[1] A mean difference of 0.00 would show equal browsing of herbicide and water treatments. A positive number indicates preference for a water treatment. Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 14--Effects of early December application of 2,4,5-T herbicide in water and diesel oil formulations on growth of Douglas-fir seedlings in early summer

Rate of application	Diesel oil carrier[1]	Living seedlings	Mean[2] height growth
Kilograms per hectare	Percent	Number	Centimeters
5.60	10	24	7.04 a
5.60	0	25	6.16 a b
3.36	0	25	6.12 a b
1.12	10	24	6.08 a b c
0	0	25	5.92 a b c d
4.48	10	23	5.48 b c d
4.48	0	25	5.44 b c d
0	10	23	5.39 b c d
2.24	0	23	5.17 b c d
0	100	23	5.00 b c d e
3.36	100	25	4.88 b c d e
3.36	10	23	4.87 b c d e
1.12	100	22	4.68 b c d e f
1.12	0	24	4.58 c d e f
2.24	10	25	4.52 d e f
2.24	100	20	3.50 e f
5.60	100	22	3.23 f
4.48	100	17	3.12 f

[1] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[2] Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 15--Effects of mid-December application of 2,4-D herbicide in water and diesel oil formulations on growth of Douglas-fir seedlings in early summer

Rate of application	Diesel oil carrier[1]	Living seedlings	Mean[2] height growth
Kilograms per hectare	Percent	Number	Centimeters
1.12	0	23	5.22 a
0	100	22	5.09 a
0	10	14	4.50 a b
4.48	10	20	4.25 a b c
0	0	25	4.24 a b
1.12	10	20	3.75 b c
2.24	0	25	3.72 b c
2.24	10	25	3.68 b c
3.36	10	25	3.52 b c
5.60	0	21	3.41 b c
1.12	100	21	3.33 b c
4.48	0	22	3.27 b c
2.24	100	23	3.09 c
3.36	0	25	2.00 d
3.36	100	25	1.64 d
5.60	100	20	1.43 d
4.48	100	20	1.05 d e
5.60	10	23	0.13 e

[1] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[2] Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 16--Comparison of growth of Douglas-fir seedlings treated with 1.12 kilograms of 2,4-D in water carrier in December (Test 2A) and February (Test 4A)

Treatment date	Living seedlings	Mean[1] height growth
	Number	Centimeters
December 19, 1977	23	5.22 a
February 13, 1978	24	1.83 b

[1] Treatment dates are significantly different at the .05-level of significance.

Table 17--Effects of mid-January applications of formulations with half-and-half mixtures of 2,4,5-T and 2,4-D herbicides in water and diesel oil carriers on growth of Douglas-fir seedlings in early summer

Rate of application	Diesel oil carrier[1]	Living seedlings	Mean[2] height growth
Kilograms per hectare	Percent	Number	Centimeters
1.12	10	25	4.92 a
0	100	25	4.68 a b
0	10	22	4.09 a b c
1.12	0	19	3.79 a b c d
0	0	23	3.78 b c d
2.24	10	24	3.46 c d e
2.24	0	25	3.42 c d e
1.12	100	25	3.06 c d e
3.36	0	25	2.86 d e f
2.24	100	23	2.48 e f g
3.36	10	24	1.83 f g h
4.48	10	23	1.63 g h
4.48	0	22	1.61 g h
3.36	100	24	1.29 h i
5.60	0	24	1.23 h i
5.60	10	23	1.11 h i
4.48	100	24	0.71 h i
5.60	100	24	0.27 i

[1] 0 = water only; 10 = 10 percent diesel oil and 90 percent water.

[2]Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Table 18--Effects of mid-February applications of fosamine, dalapon, atrazine, glyphosate, and 2,4-D herbicides in water carrier on growth of Douglas-fir seedlings in early summer

Rate of application	Formulation	Living seedlings	Mean[1] height growth
Kilograms per hectare		Number	Centimeters
5.60	atrazine	23	6.96 a
3.36	atrazine	23	6.30 a b
4.48	atrazine	20	5.85 b c
2.24	atrazine	22	5.55 b c d
0	water only	25	4.84 c d e
5.60	fosamine	25	4.52 d e f
2.24	fosamine	25	4.10 e f g
2.24	dalapon	24	3.92 e f g
4.48	dalapon	25	3.70 f g h
3.36	fosamine	23	3.33 g h i
8.96	dalapon	25	3.16 g h i
6.72	dalapon	24	2.77 h i j
1.12	glyphosate	18	2.72 h i j
4.48	fosamine	25	2.32 i j
1.12	2,4-D	24	1.83 j
4.48	glyphosate	1	1.00 e f g h i j k
2.24	glyphosate	2	0.50 i j k
3.36	glyphosate	6	0.00 k

[1] Treatment levels with a common letter are not significantly different at the .05-level of significance using Duncan's multiple-range test.

Campbell, Dan L.; Evans, James; Lindsey, Gerald D.; Dusenberry, William E. Acceptance by black-tailed deer of foliage treated with herbicides. Res. Pap. PNW-290. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; Olympia, WA: U.S. Department of the Interior, Fish and Wildlife Service, Forest-Animal Damage Control Research Project; 1981. 31 p.

To test their acceptance of foliage treated with herbicides, captive black-tailed deer were exposed to Douglas-fir seedlings and salal treated with standard formulations of 2,4,5-T, 2,4-D, atrazine, dalapon, fosamine, and glyphosate herbicides. Carriers were diesel oil and water. Tests were made from November 1977 through February 1978. Deer readily browsed 2,4,5-T treatments and most formulations of 2,4-D in oil compared with oil alone, but showed rejection of some phytotoxic glyphosate treatments. Consumption of herbicide-treated foliage did not cause noticeable health problems in test animals.

Keywords: Herbicides, browse preference, deer (black-tailed), *Odocoileus hemionus columbianus*, Douglas-fir, *Pseudotsuga menziesii*, salal, *Gaultheria shallon*, atrazine, 2,4,5-T, 2,4-D.

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